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TRAVELING PROBE FOR ZPR-II

By
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Argonne National Laboratory
Lemont, Illinois

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by

D. F. Uecker

REMOTE CONTROL ENGINEERING DIVISION

August 1953

Operated by The University of Chicago
under
Contract W-31-109-eng-38

TRAVELING PROBE FOR ZPR-II

D. F. Uecker

INTRODUCTION

In November of 1952, representatives of du Pont's Atomic Energy Division had preliminary conversations with various Argonne people concerning a movable neutron chamber for the Savannah River developmental reactor. The usefulness of such a flux measuring instrument had been demonstrated during ZPR-II experiments at Argonne.

The ZPR-II facility made provisions for probing along both horizontal and vertical axes. Separate but functionally similar probes were used for each axis: an ion chamber at one end of a length of rigid aluminum tubing was connected to its galvanometer tube and amplifier at the other end by a coaxial cable passing through the bore. This entire assembly was inserted to the desired depth in air-filled sleeves passing through the fuel lattice. Six fixed sleeves were provided in the horizontal direction, while two vertical sleeves were capable of installation in any of a multiplicity of locations.

For the Savannah River facility, it was requested that the probe not be limited to discrete axes but be capable of travel anywhere in a plane between rows of fuel. With a rigid chamber-amplifier as above, this seemed to require one or more slots in the pile face, through which the probe might operate. Difficulties of vapor-sealing such slots, restricted working space above the reactor, and gross reworking of already completed reactor designs all discouraged this alternative. Fortunately it had been demonstrated* that if the electrometer tube were located at the ion chamber, the combination could be separated from the rest of the amplifier with flexible cable. Thus, the amplifier could be fixed atop the pile face, and the chamber-electrometer only be made movable within the lattice. A number of such arrangements were considered and one selected. Du Pont's purchase order No. AXC-7488 $\frac{1}{2}$ and Argonne Work Project 198 were prepared to cover its design and construction. Responsibility for the work was placed with Argonne's Remote Control Engineering Division, and further information may be found in their file RCD-363.

The equipment is shown in Figure 1 as it was tested before shipment from Argonne. Briefly, it consists of a trolley-mounted chamber which can be moved horizontally along a track or vertically as the entire track is raised or lowered. A third power unit keeps a proper length of electrical cable paid out, the entire process being controlled and recorded at a remote location.

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*The construction and operation of the chamber and amplifier used for this application are discussed in two appendixes by J. M. Harrer of the Remote Control Eng. Div., ANL.

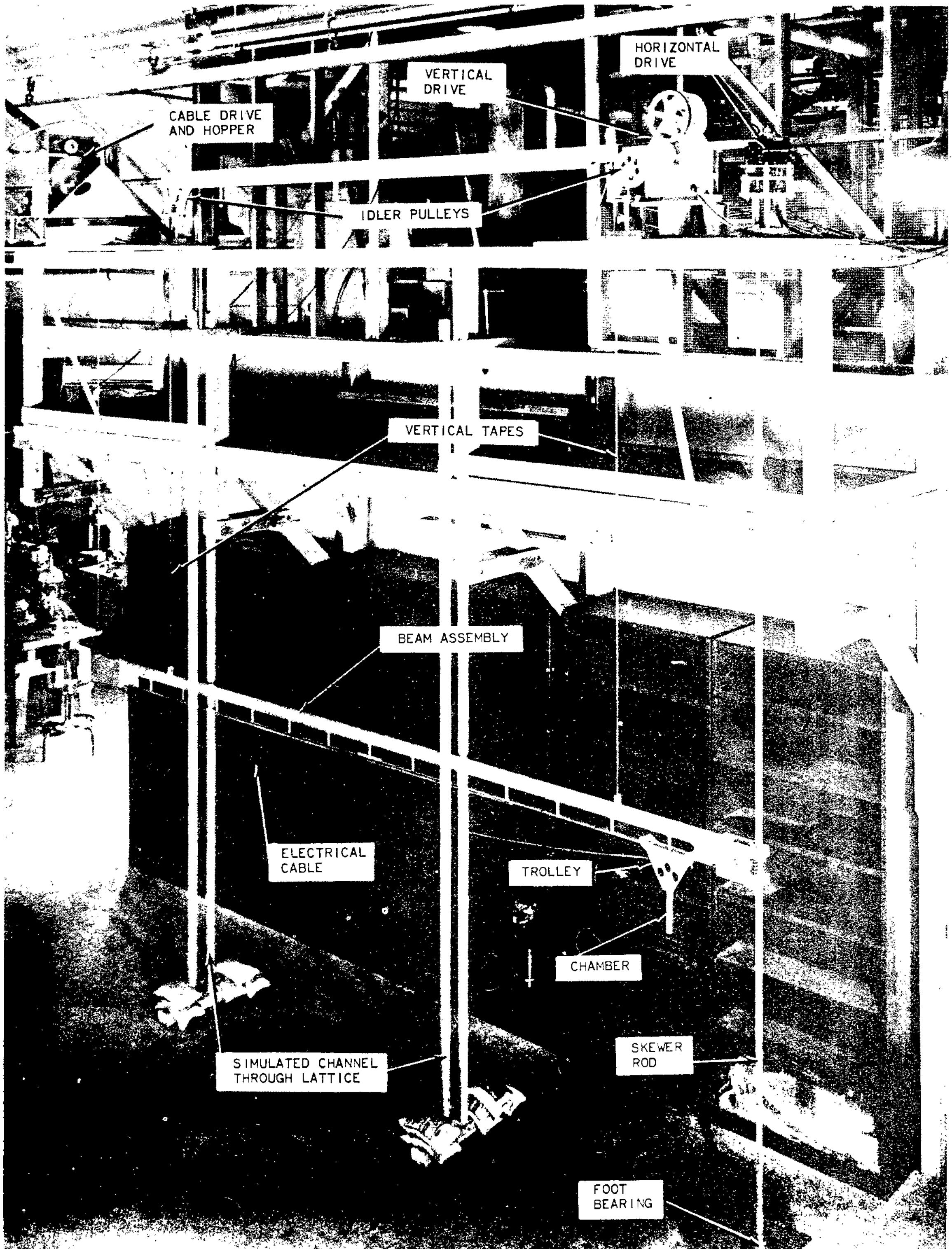
HORIZONTAL DRIVE
VERTICAL DRIVE
CABLE DRIVE AND HOPPER
IDLER PULLEYS
VERTICAL TAPES
BEAM ASSEMBLY
ELECTRICAL CABLE
TROLLEY
CHAMBER
SKEWER ROD
SIMULATED CHANNEL THROUGH LATTICE
FOOT BEARING

Figure 1

HORIZONTAL BEAM ASSEMBLY

A governing consideration for the design was that the entire system be compatible with the rest of the reactor hardware. It was observed that of the many 6 x 7 inch plates that make up the top face, a sufficient number were easily removable to provide access to any probing "channel." Accordingly, the horizontal track or beam assembly is made so that it can be inserted vertically through the opening made by removing such a plate. The trolley which runs along the track is connected to a metallic tape which passes around pulleys at either end. As seen in Figure 2, the pulley at one end is integral with a worm gear and has sprocket pins to engage holes punched in the tape. The mating worm has a cluster of four rollers disposed to rotate with it, forming an internally square hub. After the beam has been turned to a horizontal position, the square skewer rod can be inserted through the worm to engage the foot bearing, Figure 1. Subsequent rotation of the skewer rod produces horizontal motion of the chamber. As seen in Figures 2 and 3, the chamber and its trapezoidal mounting plate are easily separable from the trolley by a "teardrop hole" construction and are the last items to be installed. The special aluminum-conductor, polythene-insulated cable passes around rollers to accommodate horizontal chamber motion.

HORIZONTAL DRIVE

After the skewer rod has been inserted, the horizontal drive, Figure 4, may be installed. The package is separable into two parts by removing the three knurled thumb nuts. The lower portion replaces one of the 6 x 7 in. pile-face plates adjacent to the desired channel and is held in place by the weight of a fuel element hanging through the large, central hole. The skewer rod, whose upper end terminates in half of a flexible coupling, is inserted through the smaller hole. The drive portion may then be installed to mesh the coupling halves.

VERTICAL DRIVE

As seen in Figure 1, the beam assembly is raised and lowered by two tapes wound on a common drum. The vertical drive is shown separately in Figure 5. The base plate with its three cylindrical cuffs fits over any three fuel rods which straddle the channel being probed, and is fastened down with the special bolt. The power package, in turn, is bolted to the base plate. Comparison of Figures 4 and 5 will show the similarity between the horizontal and vertical drive units. The motors for both are synchronous and are geared to produce identical trolley speeds of about 27 inches per minute. The potentiometers are geared to make 10 turns, and the synchros 1 turn, in about 16 feet of trolley travel.

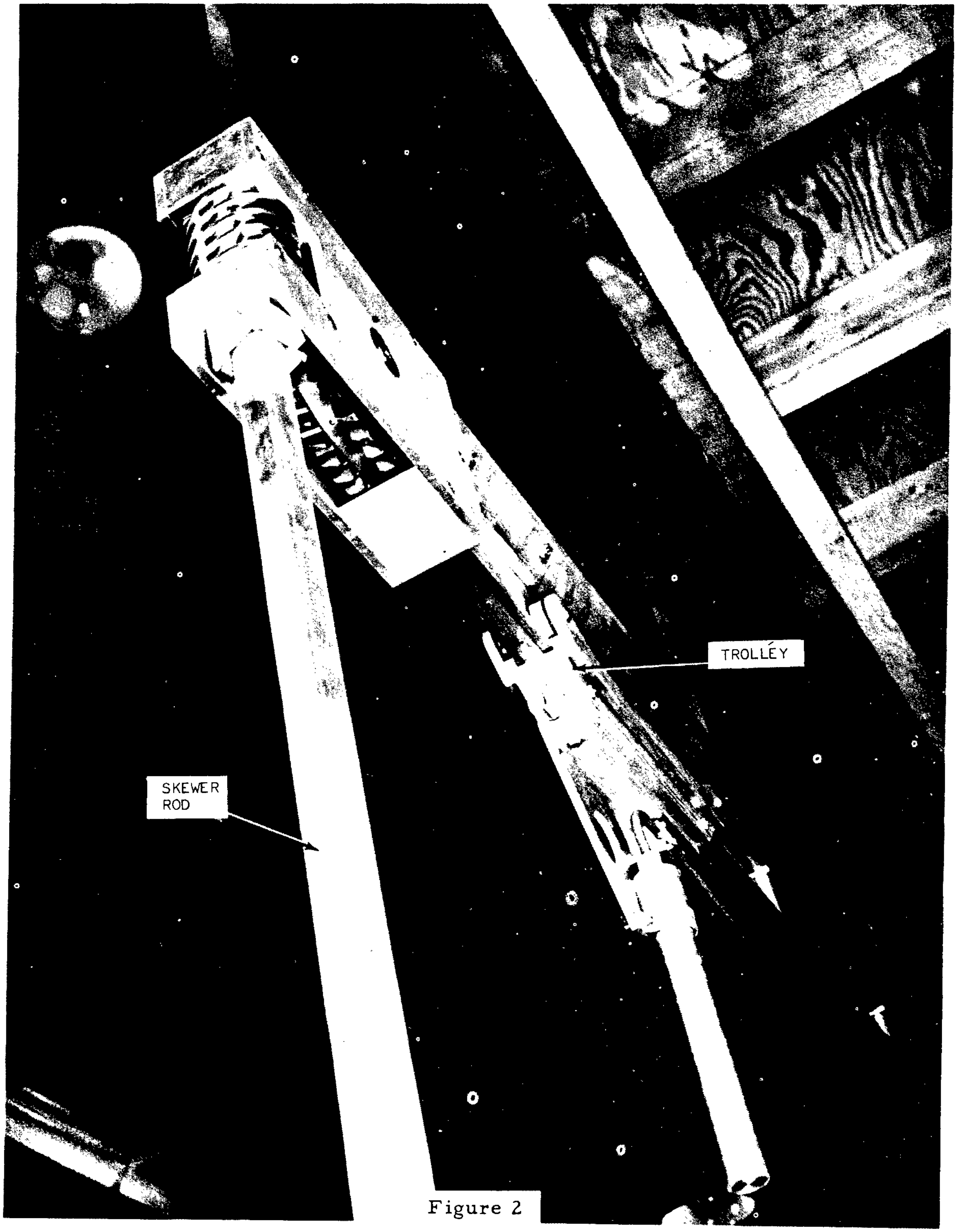

Figure 2

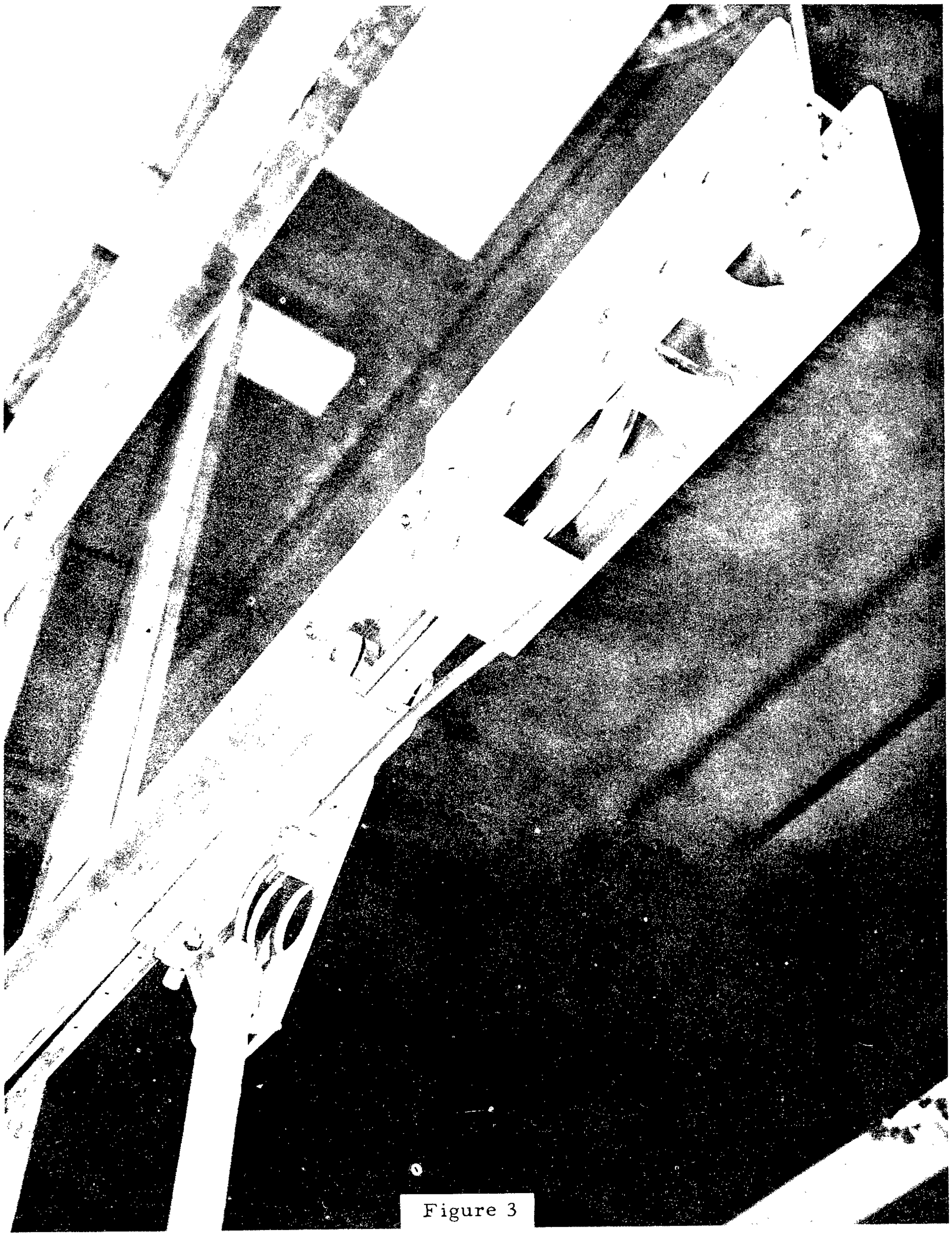

Figure 3

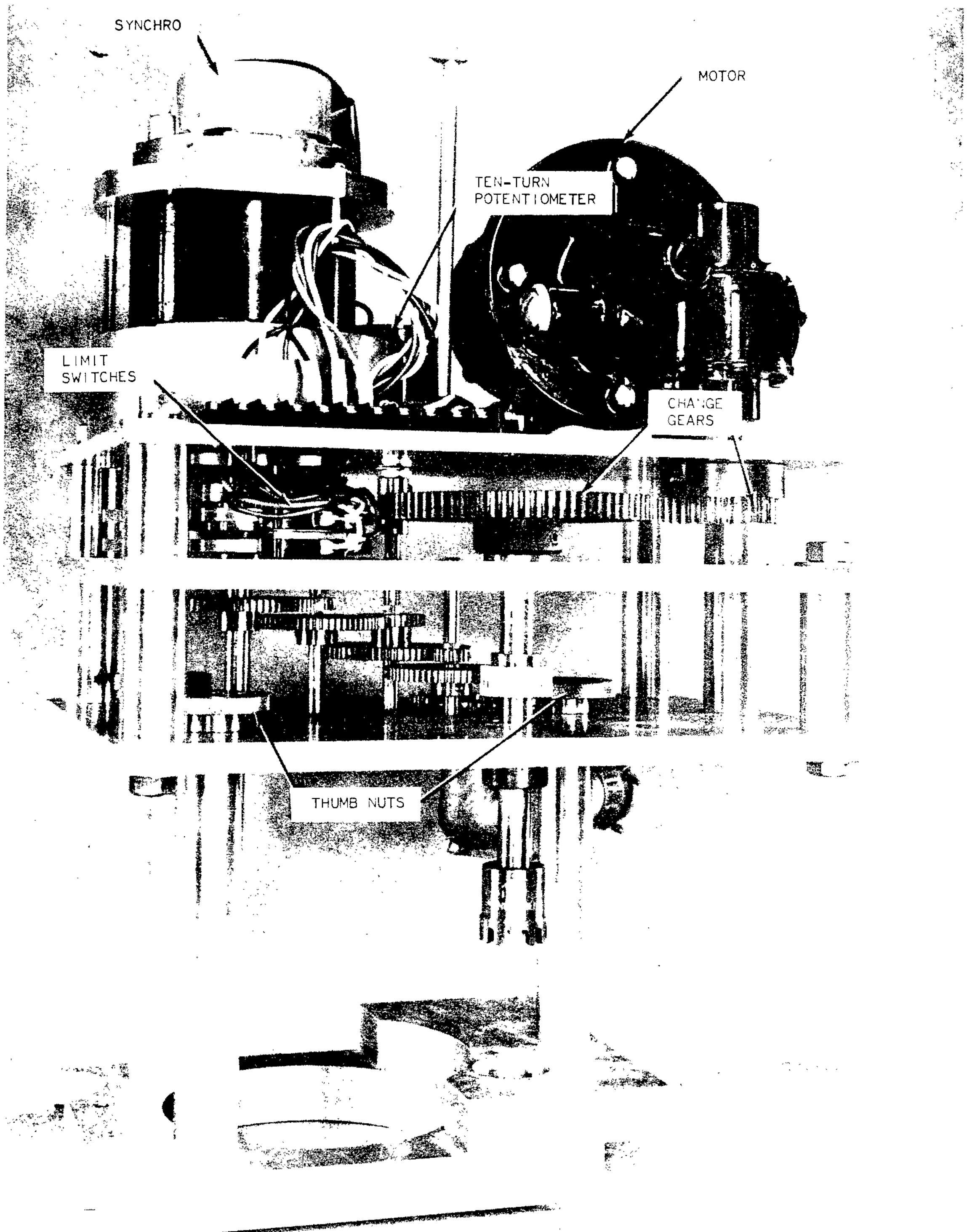
SYNCHRO
MOTOR
TEN-TURN
POTENTIOMETER
LIMIT
SWITCHES
CHANGE
GEARS
THUMB NUTS

Figure 4

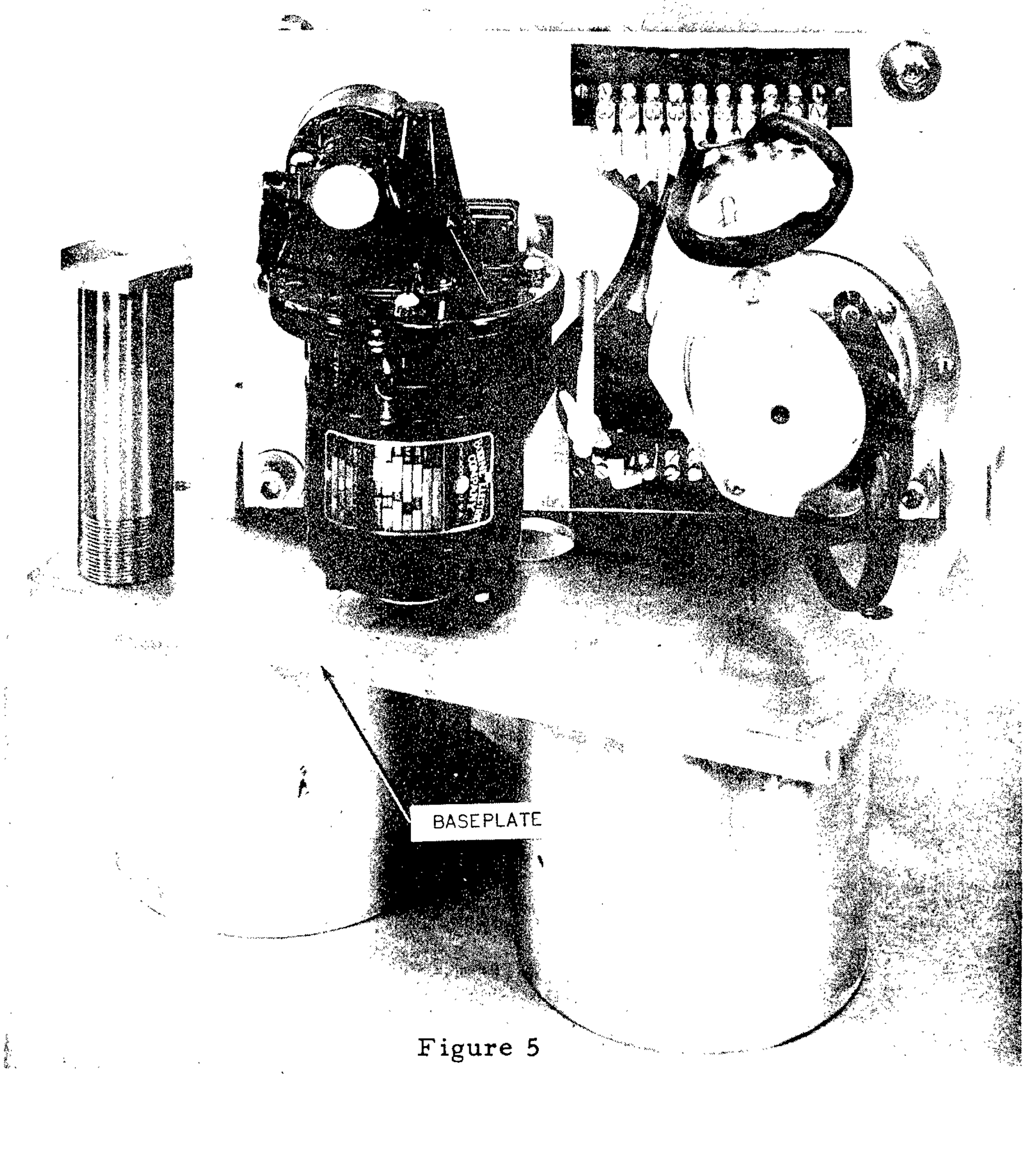

Figure 5

IDLER PULLEYS

The two tapes extend horizontally from the vertical drive package to two idler pulley assemblies, Figure 6. The special base plate replaces one of those comprising the pile face as in the case of the horizontal drive package. The .004 x $\frac{1}{2}$ inch tape passes through a split-bushing vapor seal in the plate. The pulley is supported by a pivoted fork which is spring loaded up to actuate a snap switch. With the weight of the beam assembly on the tapes, however, the pulley moves down against a mechanical stop. This slack tape detector operates if one end or the other of the beam assembly binds during vertical travel.

CABLE DRIVE

The equipment for feeding electrical cable through the pile face to the chamber is shown in Figure 7. The cable is forced into a deliberately roughened vee-grooved sheave by an idling vee belt. This arrangement develops sufficient frictional force so that, as the sheave is turned, the smooth round cable is pulled up from the reactor and pushed through the flexible metal hose into the conical hopper where coiling takes place. Figure 8 is a closer view of the sheave and the special plate through which it operates. The sheave is driven by a synchronous motor through an infinitely variable speed changer, Figure 9, so that the cable speed can be made equal to the chamber speed within close limits. The motor is electrically connected so that it is energized and deenergized coincidentally with the selected one of the trolley drive motors. Because of its different acceleration and reversal characteristics, however, it could gain or lose revolutions as a result of starting and stopping. Against this possibility, a synchro is geared to the cable drive motor, as in the case of the other two drive packages, to act as a revolution counter. The synchros are a generator, differential generator, and control transformer respectively, so that a loss of registration results in a voltage output from the control transformer. As will be seen, such output is used to indicate and correct the situation.

CONTROL STATION

Figure 10 shows the indicating and recording instruments and control panels. The topmost panel is the chamber amplifier, with meter indication of neutron flux. This output is also recorded by the "pen" axis of the two-axis strip-chart recorder. The middle panel controls the motors which drive the chamber and cable motions. The lowest panel connects the potentiometers which are geared to the horizontal and vertical drive motors into appropriate indication or recording circuits.

Figure 11 is a somewhat simplified wiring diagram of the middle panel, which controls the two motions of the trolley and the synchronization of the electric cable. The legend in quotation marks corresponds

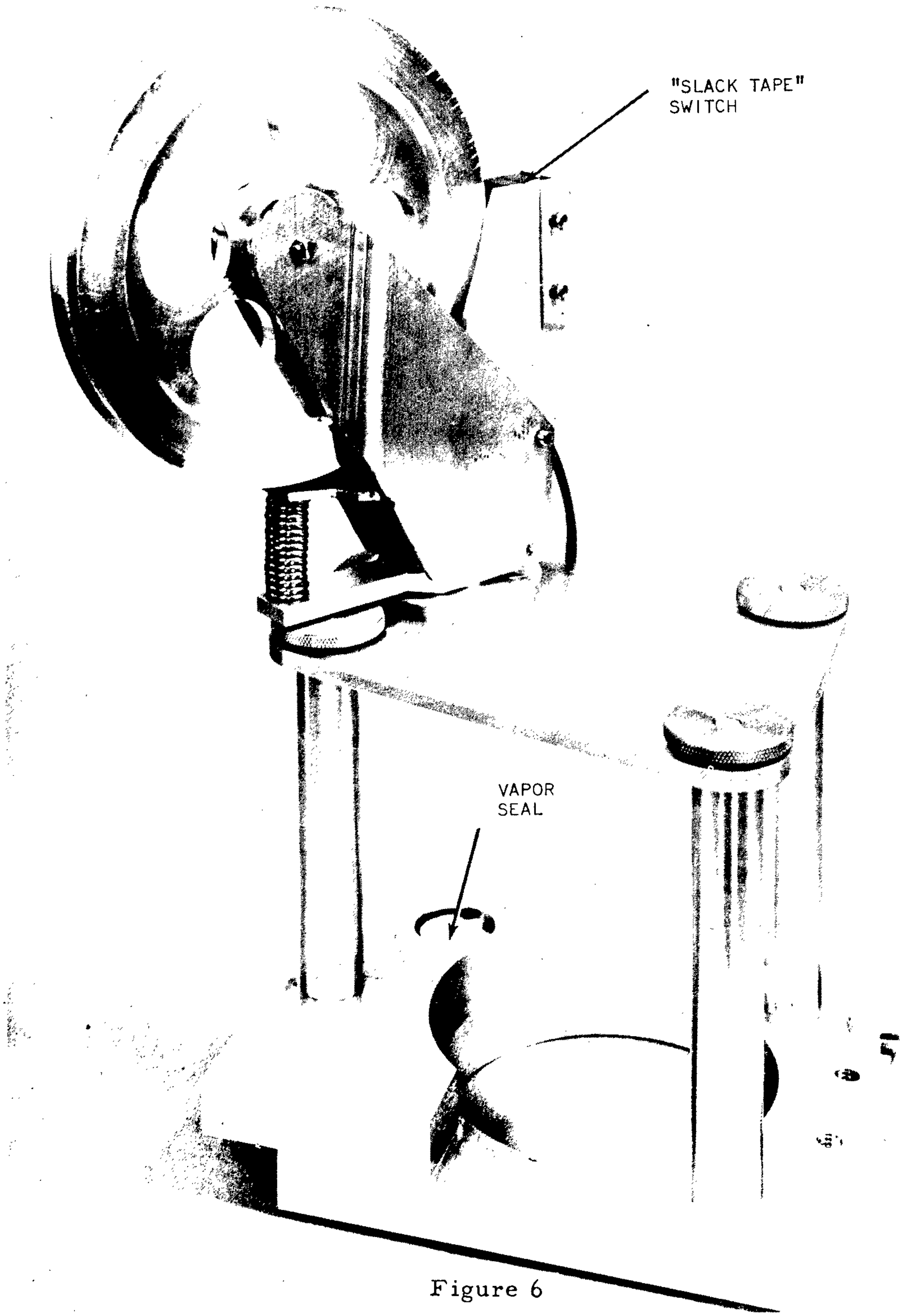

Figure 6

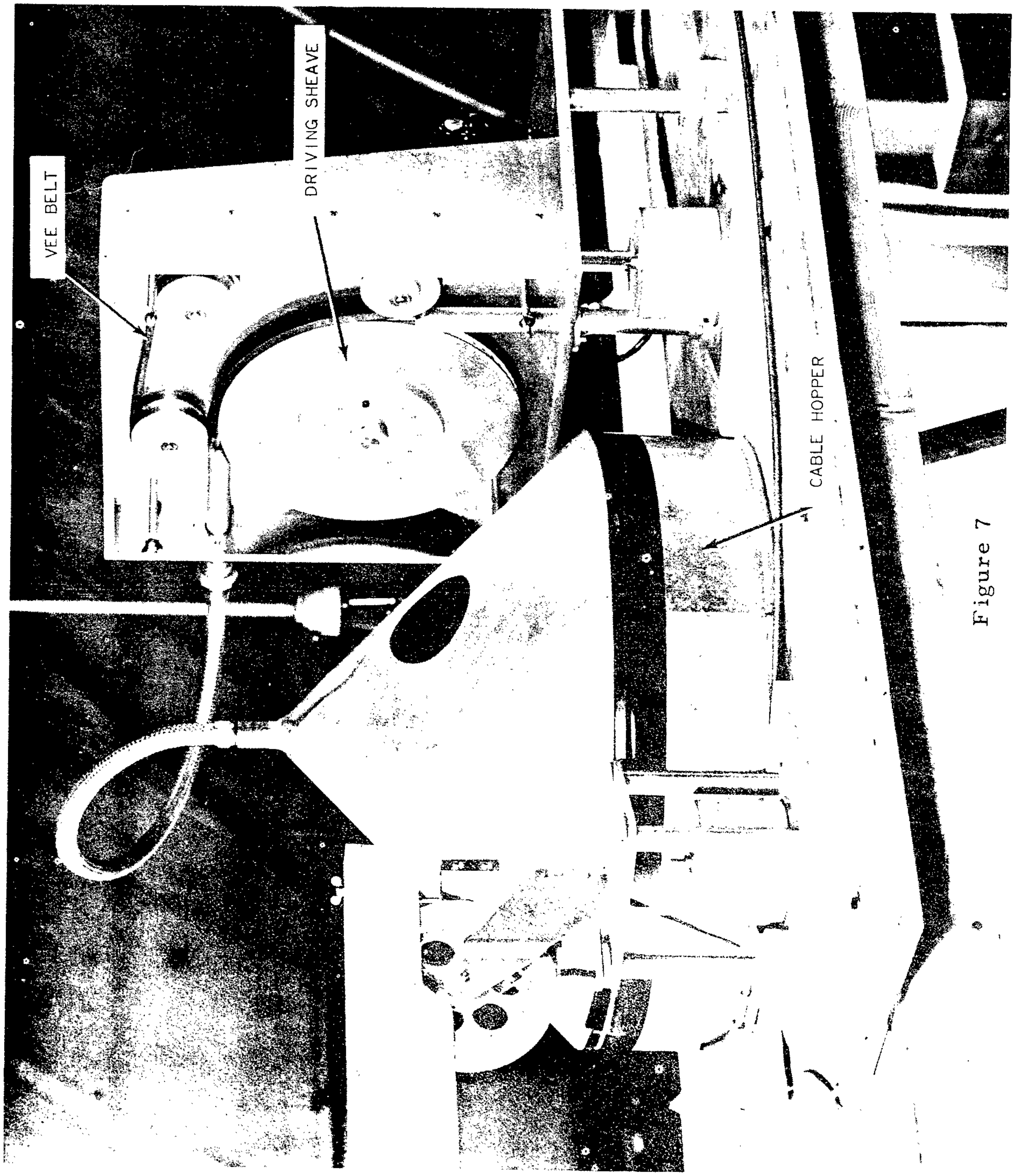

Figure 7

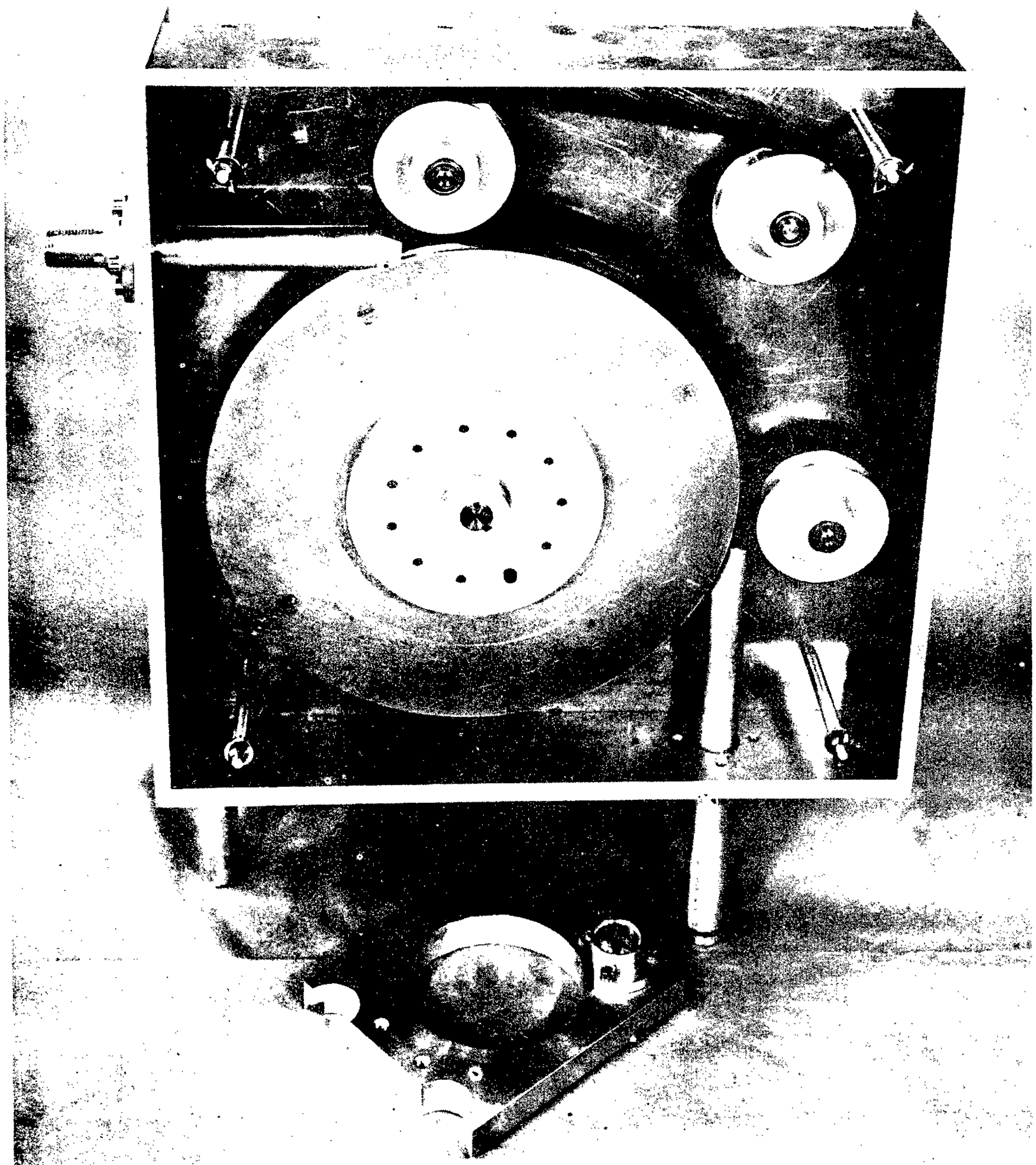

Figure 8

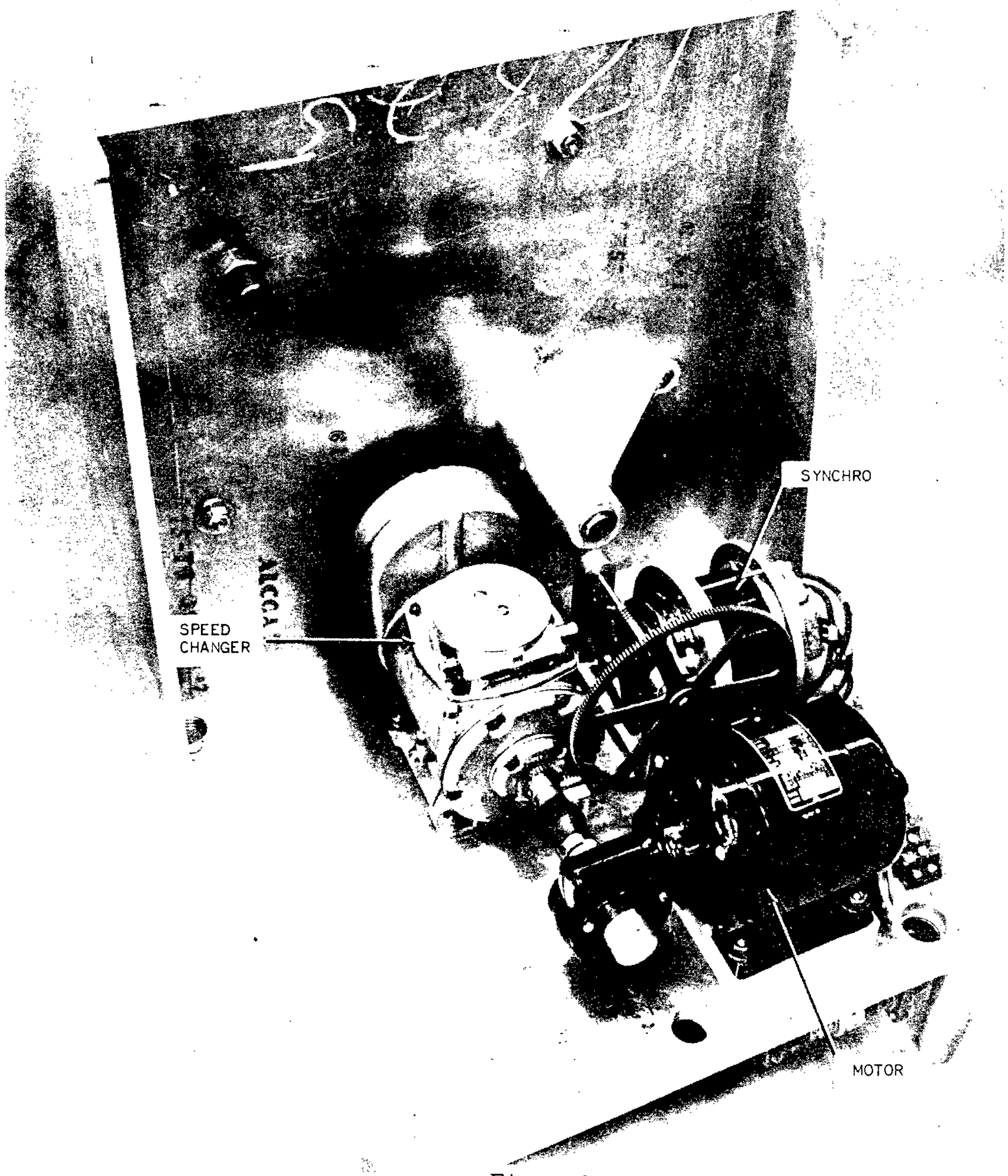

Figure 9

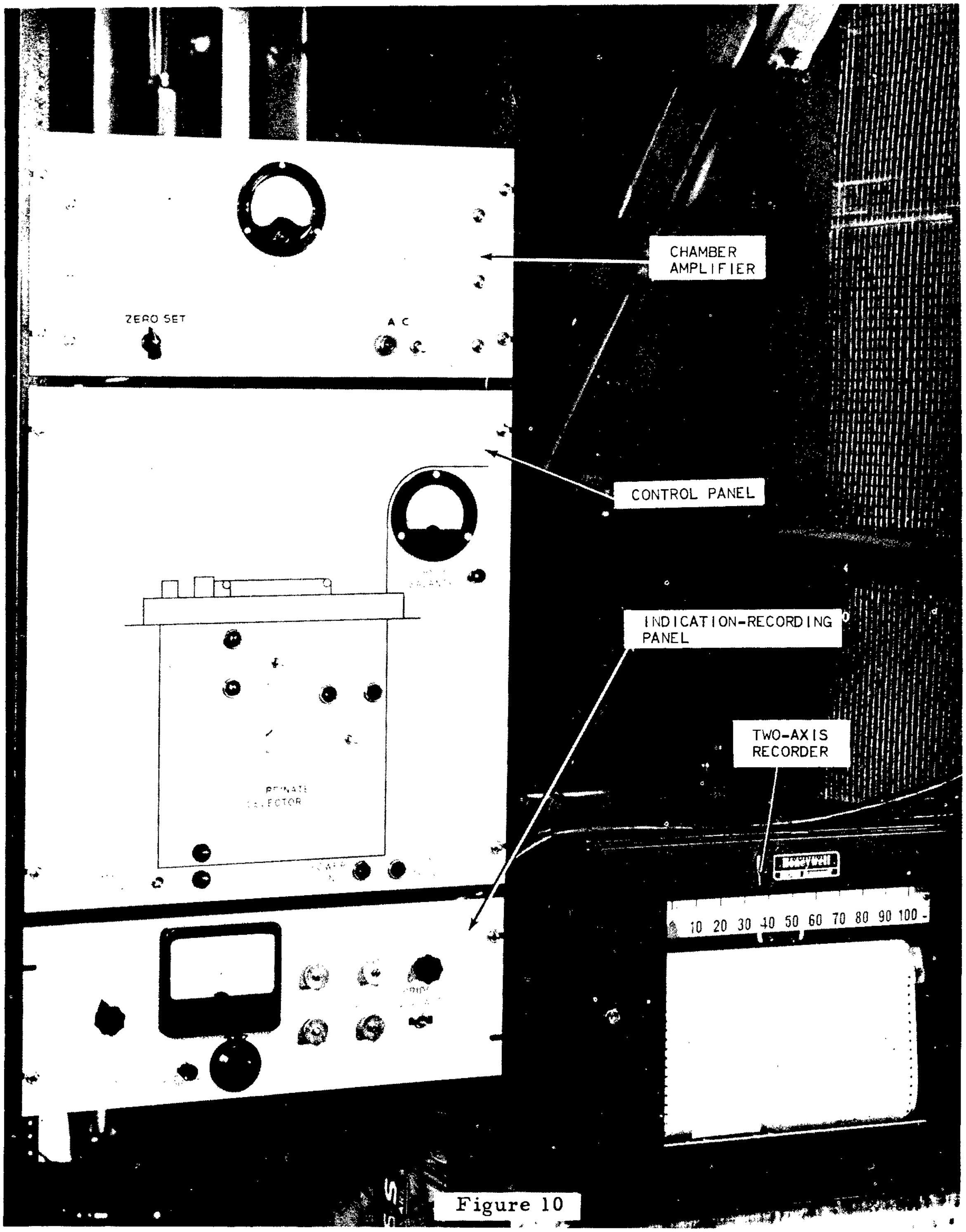
CHAMBER
AMPLIFIER
ZERO SET
A C
CONTROL PANEL
INDICATION-RECORDING
PANEL
TWO-AXIS
RECORDER
10 20 30 40 50 60 70 80 90 100

Figure 10

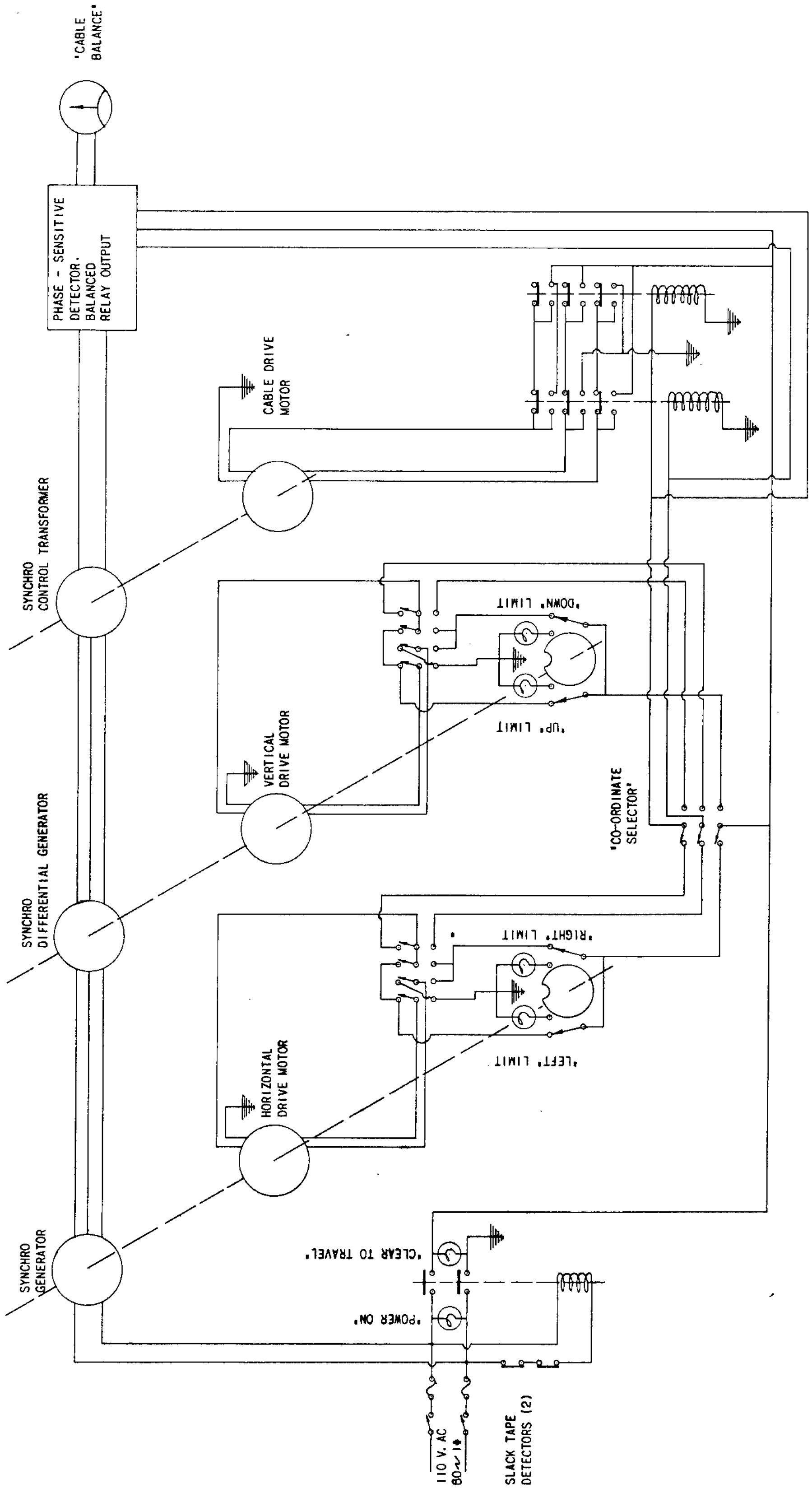
'CABLE BALANCE'
PHASE - SENSITIVE DETECTOR. BALANCED RELAY OUTPUT
CABLE DRIVE MOTOR
SYNCHRO CONTROL TRANSFORMER
'DOWN' LIMIT
'UP' LIMIT
VERTICAL DRIVE MOTOR
SYNCHRO DIFFERENTIAL GENERATOR
'CO-ORDINATE SELECTOR'
'RIGHT' LIMIT
'LEFT' LIMIT
HORIZONTAL DRIVE MOTOR
SYNCHRO GENERATOR
'CLEAR TO TRAVEL'
'POWER ON'
110 V. AC 60~ 1φ
SLACK TAPE DETECTORS (2)

FIG 11

to that in the photograph, Figure 10, and it is believed that the operation can be deduced without further description.

Figure 12 shows the circuitry provided to indicate the position of the chamber in one axis and record its motion in the other. It consists of two D. C. resistance bridges excited from a common battery. The motion-recording bridge is continuously balanced by the "paper" axis servo in the recorder. "Compress" and "Expand" potentiometers are provided so that the recording scale can be varied from about 0.5 to 2.0 in. per foot of chamber travel. The position-measuring bridge is meter-indicating and manually balanced. The over-all sensitivity of this bridge is about 1 part in 500, or $\pm$ 0.2 in. of chamber travel. A calibration was made of panel potentiometer reading vs. chamber position to eliminate the effect of potentiometer non-linearity. The over-all accuracy of the position indication bridge is therefore estimated to be $\pm$ .25 in.

CONCLUSION

The apparatus was set up at Argonne National Laboratory as shown in Figure 1 for test operation. More than 50 traverses in each axis were made, involving some 10 hours of actual running time. Several difficulties which arose were corrected early in this period. Subsequent uneventful operation and examination of the equipment by responsible du Pont representatives warranted disassembly and shipment to Savannah River for serious experimental use.

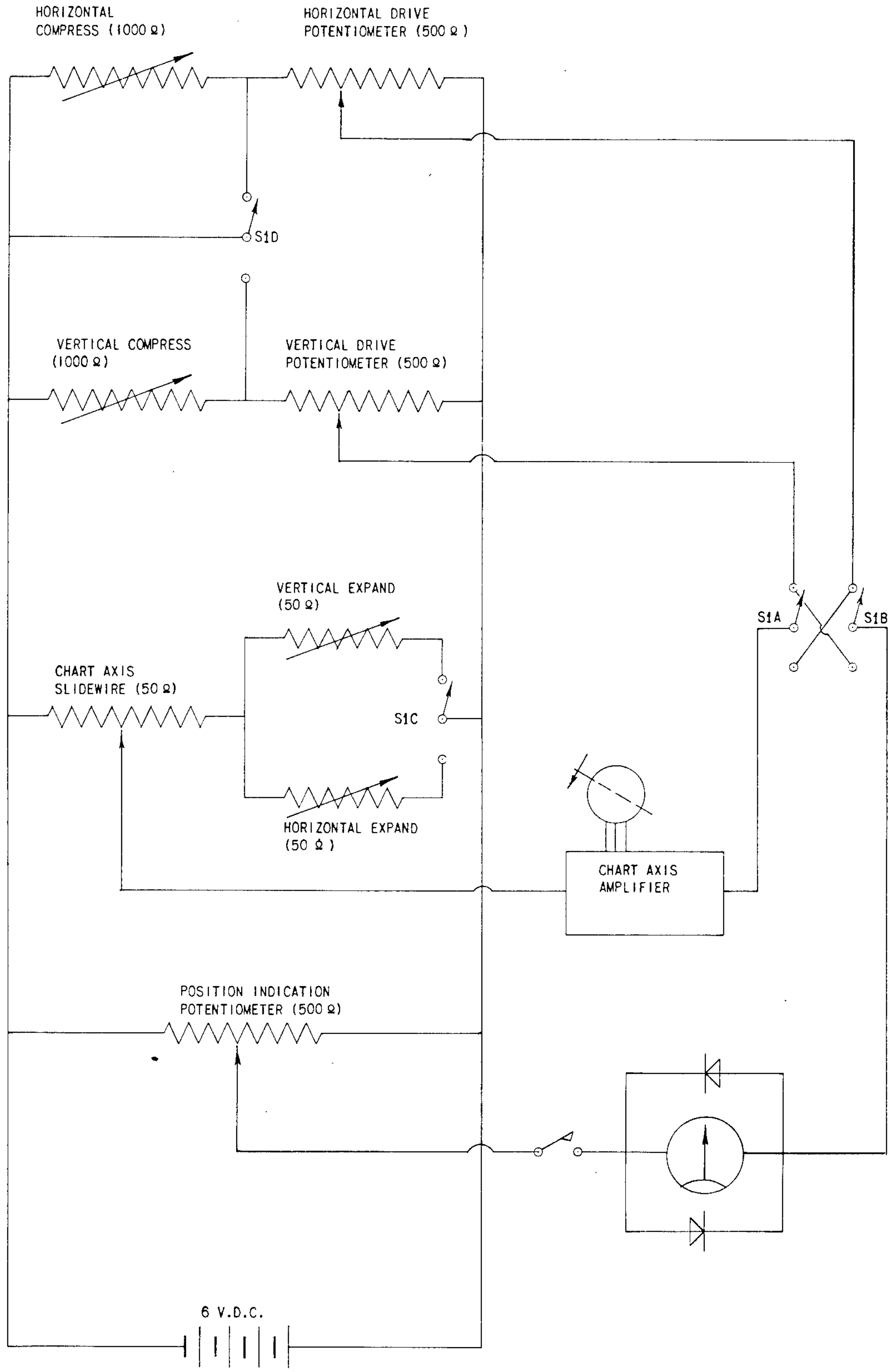
HORIZONTAL
COMPRESS (1000 Ω)
HORIZONTAL DRIVE
POTENTIOMETER (500 Ω)
S1D
VERTICAL COMPRESS
(1000 Ω)
VERTICAL DRIVE
POTENTIOMETER (500 Ω)
VERTICAL EXPAND
(50 Ω)
S1A
S1B
CHART AXIS
SLIDEWIRE (50 Ω)
S1C
HORIZONTAL EXPAND
(50 Ω)
CHART AXIS
AMPLIFIER
POSITION INDICATION
POTENTIOMETER (500 Ω)
6 V.D.C.

FIG. 12

APPENDIX I

NEUTRON PROBE CONSTRUCTION

J. M. Harrer

The electrical curcuit for flux or neutron density measurement is shown in Figure 13. The two sections of the equipment are separated by a five-conductor shielded cable. Since the shield is used as a ground, only 4 conductors are used in the cable proper, and one spare is available. The region enclosed by a dashed line is referred to as the "neutron probe" and includes the ion chamber, electrometer tube CK5889, and the 10^{10} ohm resistor. The principle of operation for this circuit is that of a negative feed back amplifier, the change in cathode voltage of the output tube being connected to offset any change in voltage which takes place at the CK5889 grid through the 10^{10} ohm resistor. Thus the voltage change at the output cathode of the 12AT7 tube is equal to the ion chamber current times 10^{10}. A zero adjustment is provided by changing the current of the CK5889 filament. The potential supply for the ion chamber is from + 150 volts through the meter and 10^4 ohm resistor.

The neutron probe is shown disassembled in Figure 14. The 5 conductor shielded cable was made by the American Phenolic Corporation to meet the following specifications:

Item 1. #22 copper conductors to consist of 7/30 T strands covered with polyethelene to .015 inch thickness.

Item 2. Cable to consist of 5 #22 conductors, Item 1, twisted together and covered with a braided aluminum shield, Item 3.

Item 3. Shield to be made of #34 aluminum wire, 9 wires forming strand of the braid. The braid to be wound with a lead of about 1.25 inches and the coverage to be about 90 %.

Item 4. Cover 5 conductor cable, Item 2, with polyethelene to a wall thickness of .040 inches. This cover is to waterproof the cable.

Item 5. Cut the cable to about 50 foot lengths and mold on to the cover a 1 inch diameter flange of polyethelene about 1 foot from the end. Tolerance on this flange to be + 1/64 inch.

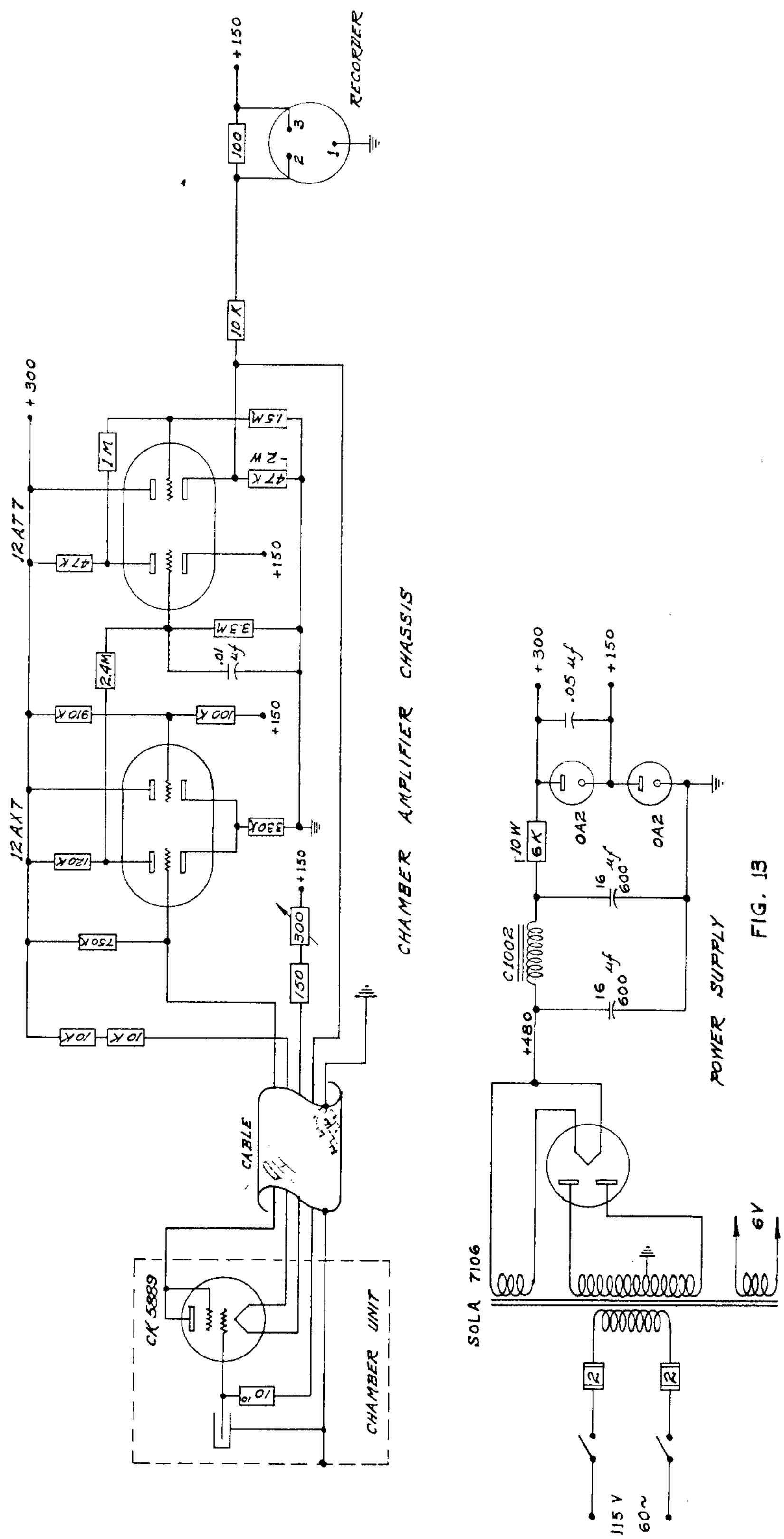
RECORDER
+150
100
10 K
+300
12AT7
12AX7
1.5M
1M
47K
2W
3.3M
.01 uf
2.4M
910K
100K
120K
330K
750K
150
300
10K
CABLE
CK 5889
CHAMBER UNIT
CHAMBER AMPLIFIER CHASSIS
.05 uf
OA2
10W
6K
16 uf 600
C1002
+480
POWER SUPPLY
SOLA 7106
6V
115 V
60~

FIG. 13

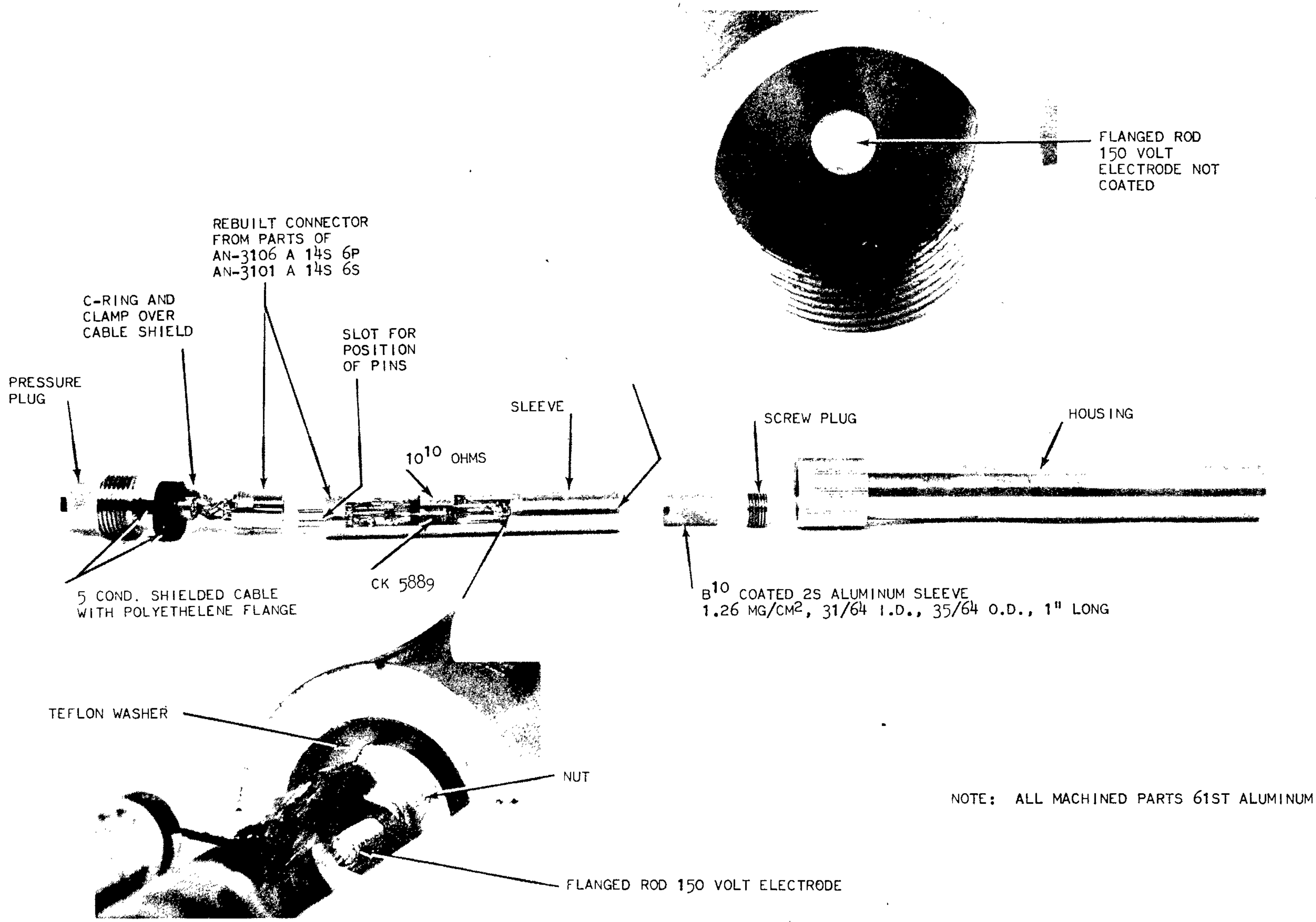
FLANGED ROD
150 VOLT
ELECTRODE NOT
COATED
REBUILT CONNECTOR
FROM PARTS OF
AN-3106 A 14S 6P
AN-3101 A 14S 6S
C-RING AND
CLAMP OVER
CABLE SHIELD
SLOT FOR
POSITION
OF PINS
PRESSURE
PLUG
SLEEVE
SCREW PLUG
HOUSING
10^{10} OHMS
5 COND. SHIELDED CABLE
WITH POLYETHELENE FLANGE
CK 5889
B^{10} COATED 2S ALUMINUM SLEEVE
1.26 MG/CM^2, 31/64 I.D., 35/64 O.D., 1" LONG
TEFLON WASHER
NUT
FLANGED ROD 150 VOLT ELECTRODE
NOTE: ALL MACHINED PARTS 61ST ALUMINUM

Figure 14